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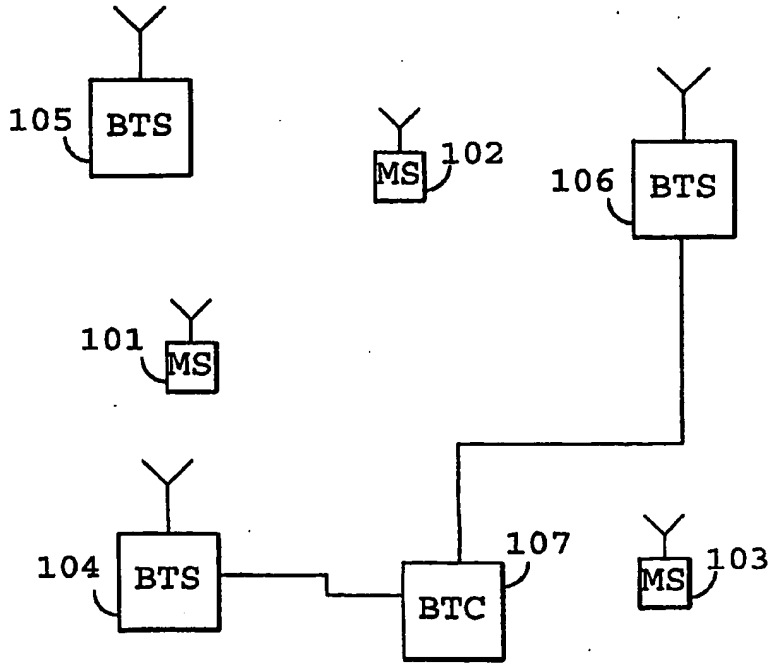
(54) Title: A METHOD OF LEVELLING A TRAFFIC LOAD OF A BASE STATION IN A CELLULAR RADIO SYSTEM, AND A CELLULAR RADIO SYSTEM

(57) Abstract

The invention relates to a method of levelling a traffic load of a base station in a cellular radio system, and a cellular radio system. The cellular radio system comprises in each cell at least one base station and a number of subscriber terminals. The base stations measure their own traffic load and transmit a pilot signal the power level of which is measured by the subscriber terminals. The base stations and the subscriber terminals are interconnected by means of their traffic channels. When a base station is heavily loaded, it reduces its coverage area by decreasing the transmit power of the pilot signal or by controlling the pilot signal power measurement of the subscriber terminal.



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A method of levelling a traffic load of a base station in a cellular radio system, and a cellular radio system

Technical field

The invention relates to a method of levelling a traffic load of a base station in a cellular radio system comprising in each cell at least one base station and a number of subscriber terminals, in which system the base stations measure their own traffic load and transmit a pilot signal the power level of which is measured by the subscriber terminals, and which base stations and subscriber terminals are interconnected by means of their traffic channels.

The invention also relates to a cellular radio system comprising in each cell at least one base station and a number of subscriber terminals, in which system the base stations transmit a pilot signal the power level of which is measured by the subscriber terminals, and which base stations and subscriber terminals are interconnected by means of their traffic channels.

Technical background

The invention is applicable in interference-limited cellular radio systems, especially in a CDMA system. In CDMA technology, a narrow-band data signal of a user is modulated to a relatively wide band by a spreading code having a broader band than the data signal. In known test systems, bandwidths such as 1.25 MHz, 10 MHz and 50 MHz have been used. A spreading code usually consists of a long pseudorandom bit sequence. The bit rate of the spreading code is much higher than that of the data signal, and the bits of the spreading code are called chips to distinguish them from data bits and data symbols. Each data symbol of the user is multiplied by all the chips of the spreading code. The narrow-band data signal thus spreads to the frequency

band used by the spreading code. Each user has a separate spreading code. Several users transmit simultaneously on the same frequency band, and the data signals are distinguished from one another in the receivers on the basis of the pseudorandom spreading code.

In the CDMA system, each base station continuously transmits a pilot signal. As it is known, a pilot signal is used to identify a base station and to form an active set in the CDMA system. The pilot signal is a data-unmodulated spreading-coded signal, which is continuously transmitted by each base station to its coverage area. A terminal equipment can identify the base stations on the basis of the pilot signal, since the spreading codes of the pilot signals differ from one another.

Subscriber terminals continuously measure pilot signals. In order to reduce the measurement load of a terminal equipment in prior art systems, each terminal equipment maintains a measurement list of the base stations and the corresponding spreading codes of the pilot signals that are situated near the terminal equipment and that are possible candidates for handover or connection establishment. The base stations on the measurement list form an active set. Terminal equipments monitor with the highest priority the pilot signals of only those base stations that are on the measurement list.

A rake receiver used in particular in the CDMA system comprises several branches, each of which may be synchronized with a different signal component. The receiver can therefore receive several signals simultaneously. On the basis of the measurements of the pilot signal, the branches of the rake receiver are caused to receive signals that arrive along different

propagation paths. The rake receiver adapts to the attenuation changes over the different connections considerably faster than the active set is updated.

The capacity of interference-limited multiple access systems, such as the CDMA cellular radio system, is determined by the disturbance power caused by the users. In such a system, a subscriber terminal usually establishes a connection with a base station with the lowest attenuation over the connection. The coverage of the base station does not in all occasions correspond to the needs of the traffic, but the load of some base stations becomes so high that connections to the subscriber terminals may break down due to either increasing disturbance or insufficient transmission capacity.

It is assumed in known handover and power control algorithms that a connection is established with the base station with the lowest attenuation over the connection. This kind of principle of selecting the best connection is advantageous when the traffic load per each base station is equal or when the signal-to-interference ratio of even the most loaded base station fulfils the minimum requirement. But when the load of a base station becomes so high that the minimum requirements concerning the quality of the connection cannot be fulfilled and the load of the adjacent base stations remains low, it is necessary to find a way to level the load. However, a prior art CDMA system does not allow the subscriber terminal to set up a connection freely with any base station, since this would result in strong interference at the base stations of adjacent cells. On the other hand, breaking down connections to some subscriber terminals in heavily loaded situations in which the quality of the connection is below the

minimum requirements and which can thus be called overloading situations, is not a desirable solution.

Characteristics of the invention

The purpose of the present invention is to implement the levelling of a traffic load of a base station with adjacent base stations in such a way that some of the subscriber terminals communicating with the base station begin to use some other base station that has a sufficiently good signal-to-interference ratio and that is lightly loaded.

This is achieved with the method of the type described in the preamble, characterized in that when the base station is heavily loaded, the base station actively reduces its coverage area.

Also, the cellular radio system according to the invention is characterized in that the base station comprises means for actively reducing its coverage area when it is heavily loaded.

The method according to the invention provides considerable advantages. The invention enables the controlled adaptation of the coverage area of a base station to overloading situations, in which the quality of the connection drops below minimum requirements. Some of the subscriber terminals of the cellular radio system, normally the subscriber terminals situated on the edge of the base station coverage area, start communicating with adjacent base stations. This is possible as long as the adjacent base stations are less loaded.

Local load peaks result especially from high transmission rate services, such as transmission of video image, provided in future systems. One connection like this can take up a considerable part of the capacity of one base station and cell. The statistical uniformity that is characteristic of the present narrow-

band services does not apply in such a case, but what is needed is the possibility of levelling the load with other base stations.

The method according to the invention can be permanently used when the different-sized coverage areas of the base stations are to be continuously kept different regardless of the loading situation. Such a network is more stable as the load is concentrated in a particular area.

The invention does not restrict the manner of handover. The handover may be soft, softer or hard.

The preferred embodiments of the method according to the invention are also disclosed in the appended dependent claims 2 to 6, and the preferred embodiments of the cellular radio system according to the invention are apparent from the appended dependent claims 8 to 12.

Description of the figures

The invention will be described in greater detail below with reference to the examples according to the accompanying drawings, in which

Figure 1 shows a cellular radio system,

Figure 2 shows a transceiver of a base station,

Figure 3 shows a transceiver of a subscriber terminal, and

Figure 4 shows the transmit power of a subscriber terminal in proportion to the distance from two different base stations.

Description of the preferred embodiments

Interference-limited multiple access systems, especially the CDMA system, in which the method according to the invention can be applied, are characterized in that the isolation between the users is finite, typically about 20 dB. In order to maintain sufficient isolation within the coverage area of a base

station, the signal powers of different users are mutually balanced by means of power control. It is preferable to maintain this balance also in a strong loading situation, when the minimum standard concerning the quality of the connection cannot be maintained, i.e. when the base station is overloaded.

In the arrangement according to the invention, the overload of a base station is cleared by transferring some of the subscriber terminals communicating with the base station to use other base stations. This is performed by actively reducing the coverage area of the base station. When the base station actively diminishes its coverage area, the reduction is most effective on the edges of the coverage area. Due to shadows caused by for example natural obstacles and buildings, the coverage area of a base station is not exactly circular nor is it necessarily uniform, wherefore the connection of a subscriber terminal to the base station depends not only on the distance but also on the propagation of radio waves in different surroundings. Therefore the subscriber terminals with the highest attenuation over the connection to the base station reducing its coverage area start using other base stations, usually adjacent base stations, and this advantageously decreases the load of the base station. The mutual power ratios of the coverage areas of the base stations are thus changed, but at the same time the internal power balance of the coverage area is maintained.

In the downlink transmission direction, the subscriber terminal measures the power ratios of the pilot signals of the base stations, and it concludes, according to known technology, what the best connection is on the basis of the power ratios. When a base station is overloaded in a preferred embodiment of the

invention, the power of the pilot signal is decreased, and the coverage area of the base station is thus reduced. It is also possible to simultaneously decrease the power of the signals of the traffic channels, so that their ratio to the disturbance of the coverage area of adjacent base stations remains the same within the reduced coverage area. Closed-loop control can further search for a more accurate power distribution in the new situation. The advantage of reducing the coverage area by decreasing the power of the pilot signal, in particular, but also the power of the traffic channels is the simplicity and the fact that the method does not increase the need for signalling in the cellular radio system.

When a base station reduces its coverage area, the subscriber terminals which have transferred to the coverage area of the adjacent base stations must employ a higher transmit power in the uplink transmission direction, since they use a connection that is less advantageous than the one used before. Therefore, at the original base station the disturbance of these subscriber terminals which started using a new base station increases. In order to compensate for this, the transmit powers of subscriber terminals within the coverage area of the original base station must be increased the same amount as the power of the base station pilot signal is decreased, so that the internal power balance in the coverage area of the base station is maintained.

In another embodiment according to the invention, the coverage area of a base station is reduced in such a way that the transmit power of the pilot signal is not exactly decreased, but the overloaded base station guides the subscriber terminals within its coverage area to make the measurement result

of the pilot signal power poorer or to otherwise worsen the result of the connection quality measurement, based on the pilot signal measurement, in such a way that some of the subscriber terminals conclude that some other base station provides a better connection. Such guidance can be performed for example in such a way that the base station transmits to the subscriber terminals a control signal on the basis of which the subscriber terminals operate. The advantage of this embodiment, too, is the rapid clearance of the overloading situation of the base station and the prevention of overloading.

In a preferred embodiment of the invention, the base station has information about the loading situation of the other base stations, for example through the signalling between the base stations, or through the base station controller, whereupon the base station reduces its coverage area in the manner according to the invention only when the load of the adjacent base stations is lighter than its own load.

Figure 1 shows a cellular radio system comprising a number of subscriber terminals 101 to 103, base stations 104 to 106, and a base station controller 107. In a preferred embodiment of the invention, the cellular radio system is a CDMA system. The base stations 104 to 106 continuously transmit a pilot signal the power level of which is measured by the subscriber terminals. It is assumed in the situation of Figure 1 that the subscriber terminals 101 and 102 communicate with the base station 104, which is so heavily loaded that the signal-to-interference ratio drops near the minimum accepted by the system. If the signal noise level drops below the operational minimum, the connection is typically broken, which is highly disadvantageous to the user. In the arrangement according to the invention, the base station 104 reduces

its coverage area by decreasing the effective value of its pilot signal, which in a preferred arrangement means that the transmit power of the pilot signal is diminished. The advantage of this arrangement is that it does not increase signalling and it is simple to realize. The subscriber terminals 101 and 102 thus conclude on the basis of the pilot signal measurements that the connection to the base station 104 has deteriorated. However, the connection of the subscriber terminal 101 to the base station 104 remains good since this terminal is close to the base station 104 and there are no natural obstacles or the like between them. Since the subscriber terminal 102 is a little further from the base station 104 than the subscriber terminal 101, its situation changes more as a result of the decrease in the transmit power of the base station 104. Based on the measurement of the pilot signal, the connection of the subscriber terminal 102 to the base station 104 in turn deteriorates to such an extent that the subscriber terminal 102 concludes that the connection to the base station 106 is of better quality and changes thereto. The situation of the subscriber terminal 103 also changes. It is assumed in Figure 1 that the subscriber terminal 103 is in the process of establishing a connection with a base station. If the base station 104 were not overloaded, the subscriber terminal 103 would form a connection with it. However, since the base station 104 has reduced its coverage area due to the overload by decreasing especially the transmit power of the pilot signal, the subscriber terminal 103 sets up a connection with some other base station. Therefore, when the base station 104 decreases, due to overloading, the pilot signal transmit power or in general the effective value of the pilot signal, it simultaneously

clears the harmful overloading situation and also prevents the occurrence of new overloading situations.

Figure 2 is a diagram illustrating a base station transceiver in which the method according to the invention can be applied. The receiving part of the base station comprises a receiver unit 216 receiving a signal that is converted to an intermediate frequency, and converter means 218 in which the signal is converted to a digital form. The converted signal is supplied to detector means 220 from where the detected signal is supplied further to de-interleaving means 222 and to means 224 wherein the received signal is decoded, i.e. subjected to both channel and speech decoding. The detector means 220 also measure the loading situation of the base station. The transmitting part of the base station further comprises means 200 for encoding the signal to be transmitted. The encoded signal is supplied to means 202 for interleaving the encoded signal. The output signal of the interleaving means is connected to the input of the means 204, where the burst to be transmitted is formed. The resulting signal is supplied to modulation means 208, the output signal of which is supplied via a transmitter unit 210 and a duplex filter 212 to an antenna 214. The aforementioned blocks can be implemented in known manners.

The apparatus further comprises control and counting means 226, which control the operation of the other aforementioned blocks. The control means 226 may be used to adjust the transmit power of the base station, and the control means comprise pilot-signal control means 226a, with which the transmit power of the pilot signal is controlled in an embodiment of the invention. The detector means 220, which are used to monitor the loading situation of the base station, adjust the transmit power of the pilot signal and also

the signals of the traffic channels together with the control means 226 and the entire transmitting part. This provides the advantage that the base station can reduce its coverage area and thus clear up and prevent an overloading situation of the base station. Adjusting the transmit power of the pilot signals of the base stations also provides the advantage that the interference level caused by the base stations can be decreased, since the transmit power can be optimized to suit each situation. In an embodiment according to the invention, the control means 226a also form and transmit, via the transmitting part, a control signal decreasing the result of measurement performed by the subscriber terminal on the power level of the pilot signal. This arrangement has the same effect on the operation of the subscriber terminal as the actual reduction of the transmit power of the pilot signal. The control means 226 and 226a of the base station are typically realized by means of a processor, but they may also be realized with several other kinds of electronic connections, which may perform similar functions as a processor.

Figure 3 illustrates a transceiver of a subscriber terminal in a cellular radio system, the transceiver being largely similar to the transceiver of a base station. The subscriber terminal comprises control and counting means 226, which control the operation of other blocks. The control means 226 receive and compare the signals of different base stations. The control means 226 can also be used to adjust the transmit power of the base station. The control means 226 of the subscriber terminal are typically realized by means of a processor. The subscriber terminal also comprises means 220 and 226 for measuring the strength of a pilot signal it has received from the base station. If the system is a CDMA system, the detector block of

the receiver, usually realized according to the rake principle, typically comprises several receiver branches, at least one of which is a so-called searcher branch which measures especially the strengths of the pilot signals. On the basis of the measurement of the pilot signals, the subscriber terminal selects and, if necessary, changes the base station with which it communicates.

Figure 4 shows in a simplified manner the transmit power of a subscriber terminal as a function of distance from two different base stations. This illustrates the change in audibility as the base station decreases the transmit power of the pilot signal. Figure 4 does not take into account natural or other obstacles restricting the propagation of the radio waves. The power of the pilot signal of the base station BS2 has been reduced by d. Due to this, the coverage area of the base station has shifted from B to B', where the attenuation to the base station BS2 is lower by the value amount of d than the attenuation to the base station BS1. The subscriber terminal originally transmits with such a power that the signal power received at the closest base station is equally high. After the power reduction of the pilot signal, a subscriber terminal situated at the new border of audibility B' of the base station transmits with the same power regardless of which base station it communicates with. In order to maintain the balance of power, a subscriber terminal situated closer to the base station BS2 must also increase its transmit power.

Even though the invention is described above with reference to the example according to the accompanying drawings, it is clear that the invention is not restricted thereto, but it can be modified in

many ways within the scope of the inventive idea disclosed in the appended claims.

Claims:

1. A method of levelling a traffic load of a base station in a cellular radio system comprising in each cell at least one base station (104 - 106) and a number of subscriber terminals (101 - 103), in which system the base stations (104 - 106) measure their own traffic load and transmit a pilot signal the power level of which is measured by the subscriber terminals (101 - 103), and which base stations (104 - 106) and subscriber terminals (101 - 103) are interconnected by means of their traffic channels, c h a r a c t e r i z e d in that when the base station (104) is heavily loaded, the base station (104) actively reduces its coverage area.

2. A method according to claim 1, c h a r a c t e r i z e d in that the base station (101) reduces its coverage area by decreasing the effective power level of the pilot signal (108) it transmits.

3. A method according to claim 2, c h a r a c t e r i z e d in that in addition to decreasing the effective power level of the pilot signal (108), the base station (104) decreases the transmit power of its traffic channels.

4. A method according to claim 2, c h a r a c t e r i z e d in that the effective power level of the pilot signal (108) is decreased in such a way that the base station (104) decreases the transmit power of its pilot signal (108).

5. A method according to claim 2, c h a r a c t e r i z e d in that the effective power level of the pilot signal (108) is decreased in such a way that as the transmit power of the pilot signal (108) remains unchanged, the base station (104) transmits a control signal by means of which the measurement result of the

pilot signal power level of the subscriber terminal (101, 102) is decreased.

6. A method according to claim 1, c h a r a c t e r i z e d in that the base station (104 - 106) compares its own load and the load of the adjacent base stations, and reduces its coverage area only when the load of the base station (104 - 106) itself is higher than that of the adjacent base stations.

7. A method according to claim 1, c h a r a c t e r i z e d in that the subscriber terminals (102) left outside the coverage area of the base station after the base station (104) has reduced its coverage area start using some other base station, and simultaneously the subscriber terminals (102) increase their transmit power by the same or almost the same amount in proportion to the amount the base station (104) reduced its coverage area.

8. A cellular radio system comprising in each cell at least one base station (104 - 106) and a number of subscriber terminals (101 - 103), in which system the base stations (104 - 106) transmit a pilot signal the power level of which is measured by the subscriber terminals, and which base stations and subscriber terminals are interconnected by means of their traffic channels, c h a r a c t e r i z e d in that the base station (104) comprises means (226a) for actively reducing its coverage area when it is heavily loaded.

9. A cellular radio system according to claim 8, c h a r a c t e r i z e d in that the base station (104) comprises means (226a) for decreasing the effective power of its pilot signal (108).

10. A cellular radio system according to claim 8, c h a r a c t e r i z e d in that the base station (104) comprises means (226a) for decreasing the transmit power of its traffic channels.

11. A cellular radio system according to claim 8, c h a r a c t e r i z e d in that the base station (104) comprises means (226a) for decreasing the transmit power of its pilot signal.

12. A cellular radio system according to claim 8, c h a r a c t e r i z e d in that the base station (104) comprises means (226a) for decreasing the pilot signal power level measured by the subscriber terminal.

13. A cellular radio system according to claim 8, c h a r a c t e r i z e d in that the base station (104) comprises means (220 and 226) for comparing its own load and the load of the adjacent base stations, and means (226a) for reducing its coverage area only when the load of the base station (104) itself is higher than the load of the adjacent base stations.

AMENDED CLAIMS

[received by the International Bureau on 7 October 1996 (07.10.96); original claims 1-13 replaced by new claims 1-9 (3 pages)]

1. A method of levelling a traffic load of a base station in a cellular radio system comprising in each cell at least one base station (104 - 106) and a number of subscriber terminals (101 - 103), in which system the base stations (104 - 106) measure their own traffic load and transmit a pilot signal the power level of which is measured by the subscriber terminals (101 - 103), and which base stations (104 - 106) and subscriber terminals (101 - 103) are interconnected by means of their traffic channels, and in which system when the base station (104) is heavily loaded, the base station (104) actively reduces its coverage area by decreasing the power level of the pilot signal (108) it transmits, c h a r a c t e r i z e d in that the reduction of the power level of the pilot signal (108) transmitted by the base station (104) is carried out by decreasing the effective power level of the pilot signal (108), and that the base station (104) decreases the transmit power of its traffic channels.

2. A method according to claim 1, c h a r a c t e r i z e d in that the effective power level of the pilot signal (108) is decreased in such a way that the base station (104) decreases the transmit power of its pilot signal (108).

3. A method according to claim 1, c h a r a c t e r i z e d in that the effective power level of the pilot signal (108) is decreased in such a way that as the transmit power of the pilot signal (108) remains unchanged, the base station (104) transmits a control signal by means of which the measurement result of the pilot signal power level of the subscriber terminal (101, 102) is decreased.

4. A method according to claim 1, c h a r a c t e r i z e d in that the base station (104 - 106) compares its own load and the load of the adjacent base stations, and reduces its coverage area only when the load of the base station (104 - 106) itself is higher than that of the adjacent base stations.

5. A method according to claim 1, c h a r a c t e r i z e d in that the subscriber terminals (102) left outside the coverage area of the base station after the base station (104) has reduced its coverage area start using some other base station, and simultaneously the subscriber terminals (102) increase their transmit power by the same or almost the same amount in proportion to the amount the base station (104) reduced its coverage area.

6. A cellular radio system comprising in each cell at least one base station (104 - 106) and a number of subscriber terminals (101 - 103), in which system the base stations (104 - 106) measure their own traffic load and transmit a pilot signal the power level of which is measured by the subscriber terminals (101 - 103), and which base stations (104 - 106) and subscriber terminals (101 - 103) are interconnected by means of their traffic channels, and in which system when the base station (104) is heavily loaded, the base station (104) actively reduces its coverage area by decreasing the power level of the pilot signal (108) it transmits, c h a r a c t e r i z e d in that the base station (104) comprises means (226a) for reducing the effective power of its pilot signal (108), and that the base station (104) comprises means (226a) for reducing the transmit power of its traffic channels.

7. A cellular radio system according to claim 6, c h a r a c t e r i z e d in that the base station (104) comprises means (226a) for decreasing the transmit power of its pilot signal.

8. A cellular radio system according to claim 6,

characterized in that the base station (104) comprises means (226a) for decreasing the pilot signal power level measured by the subscriber terminal.

9. A cellular radio system according to claim 6, characterized in that the base station (104) comprises means (220 and 226) for comparing its own load and the load of the adjacent base stations, and means (226a) for reducing its coverage area only when the load of the base station (104) itself is higher than the load of the adjacent base stations.

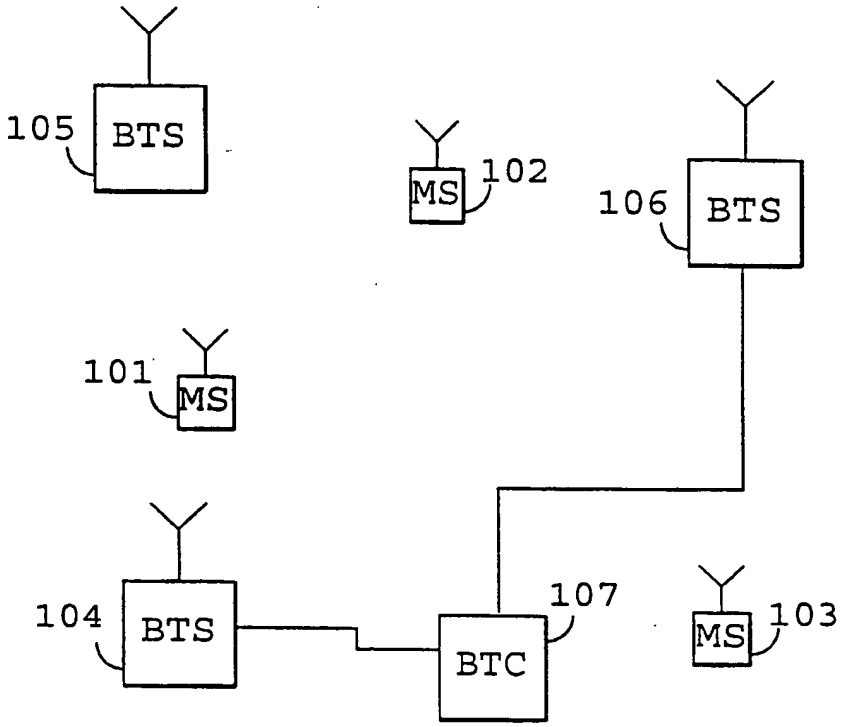

Fig. 1

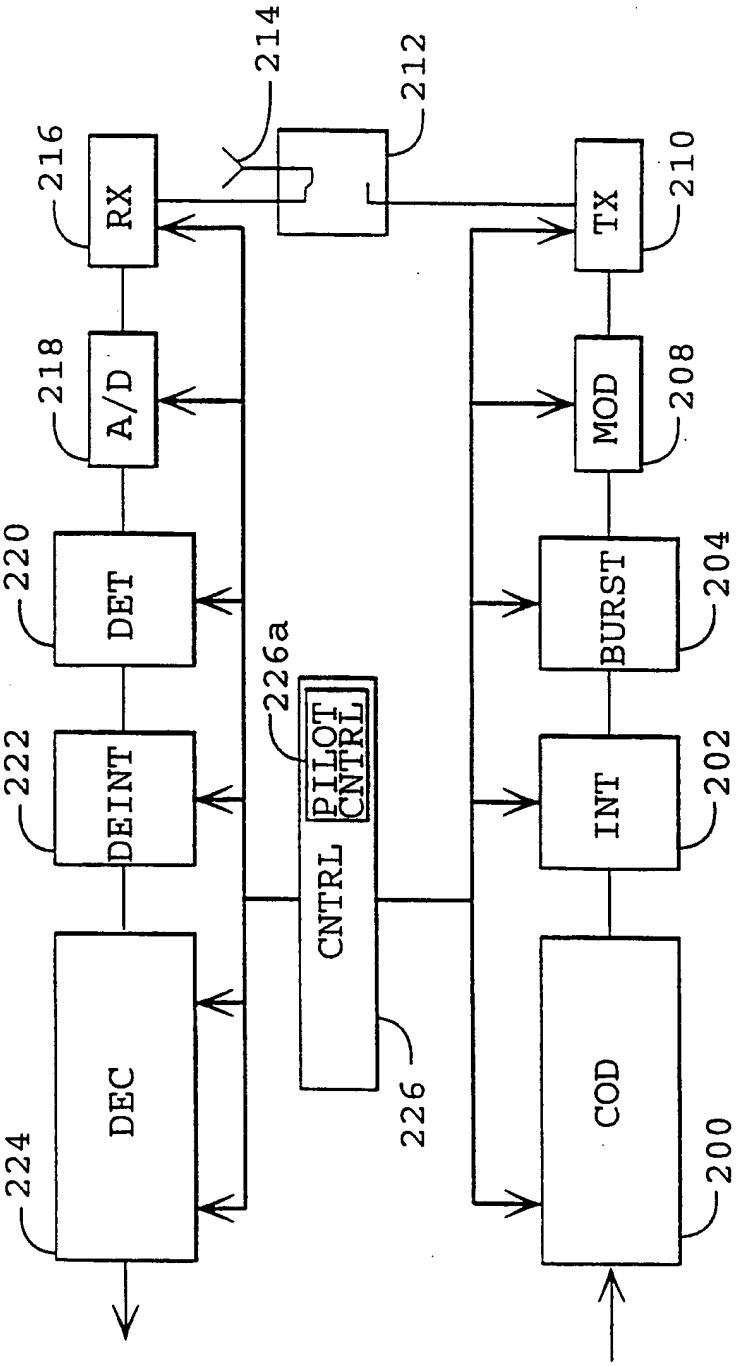
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Fig. 2

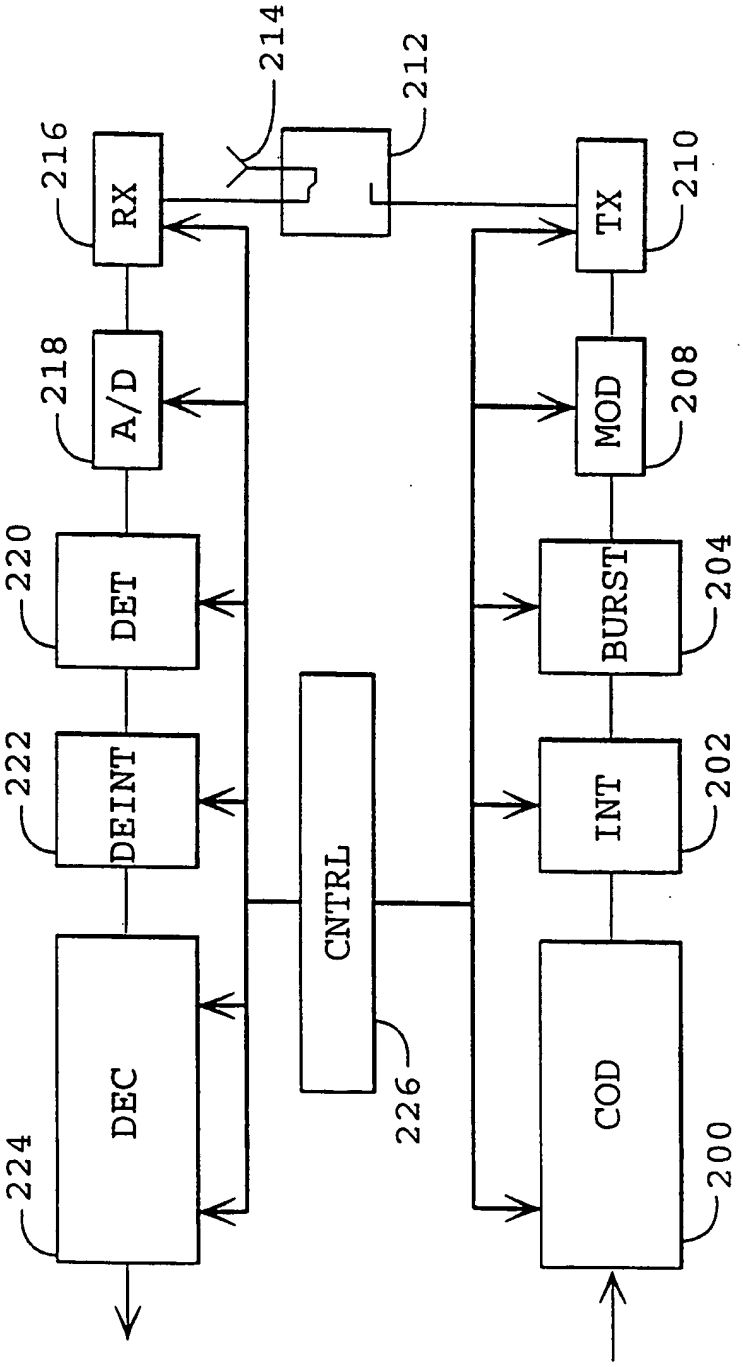
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Fig. 3

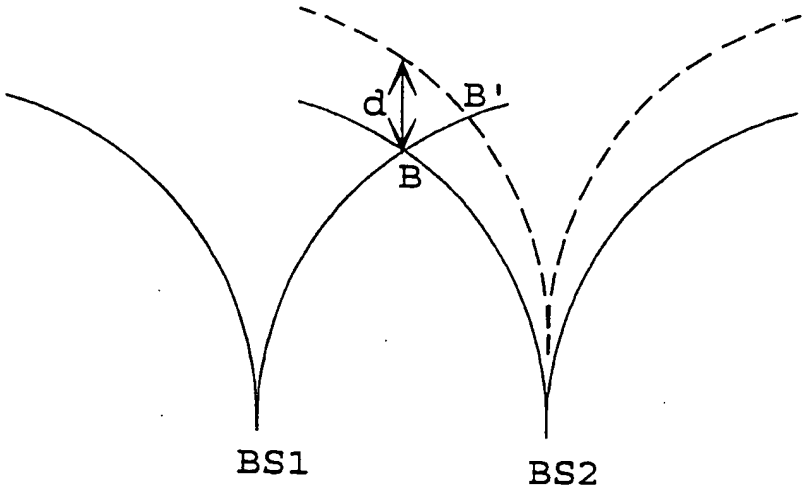

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04Q 7/36, H04Q 7/30
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0615395 A1 (HITACHI, LTD), 14 Sept 1994 (14.09.94), page 3, line 14 - line 47, figures 5-6, abstract, see whole document --	1-13
X	US 5428817 A (MASAHIKO YAHAGI), 27 June 1995 (27.06.95), column 1, line 66 - column 2, line 14; column 3, line 44 - line 49 --	1-13
A	WO 9312587 A1 (NOKIA TELECOMMUNICATIONS OY), 24 June 1993 (24.06.93), page 2, line 10 - line 35 --	1-13

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 June 1996	18 -06- 1996
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Marcus Wik Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 95/00466

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5276907 A (REUVEN MEIDAN), 4 January 1994 (04.01.94), column 6, line 33 - line 45, abstract -- --------	1-13

INTERNATIONAL SEARCH REPORT

01/04/96

International application No.
PCT/FI 95/00466

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US-A- 5428817	27/06/95	JP-A- 5344048	24/12/93
WO-A1- 9312587	24/06/93	AT-T- 130141	15/11/95
		AU-B- 665596	11/01/96
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		FI-A- 915886	14/06/93
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		IL-A- 100569	29/06/95
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		WO-A,A- 9212601	23/07/92